Chemistry & Climate Impact of Sulfuric Acid Hazes on Early Venus

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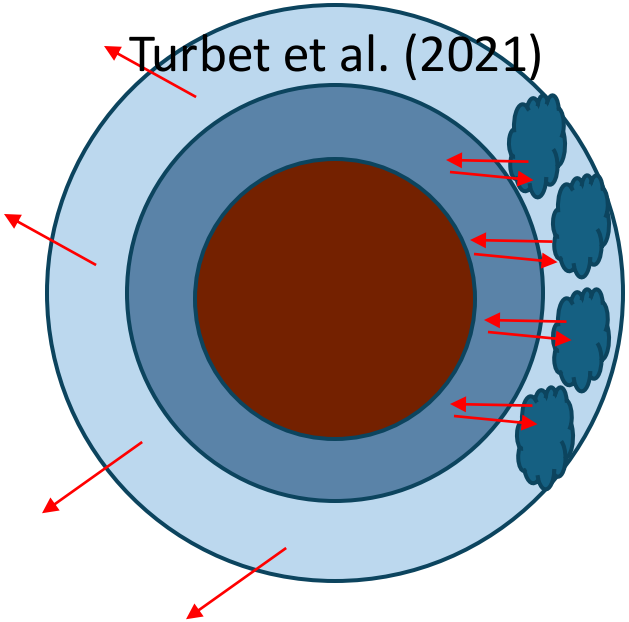
Early Venus

Nightside clouds dominated the early Venus climate.

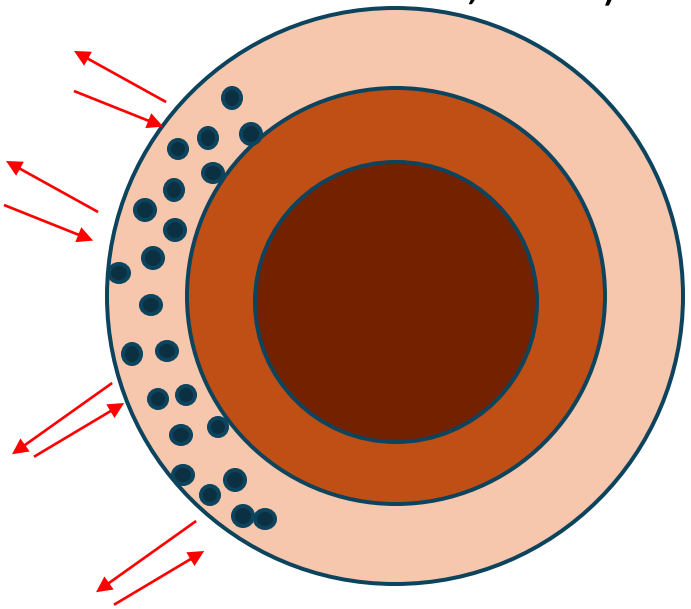
The greenhouse prevented oceans from forming.

Turbet et al. (2021)

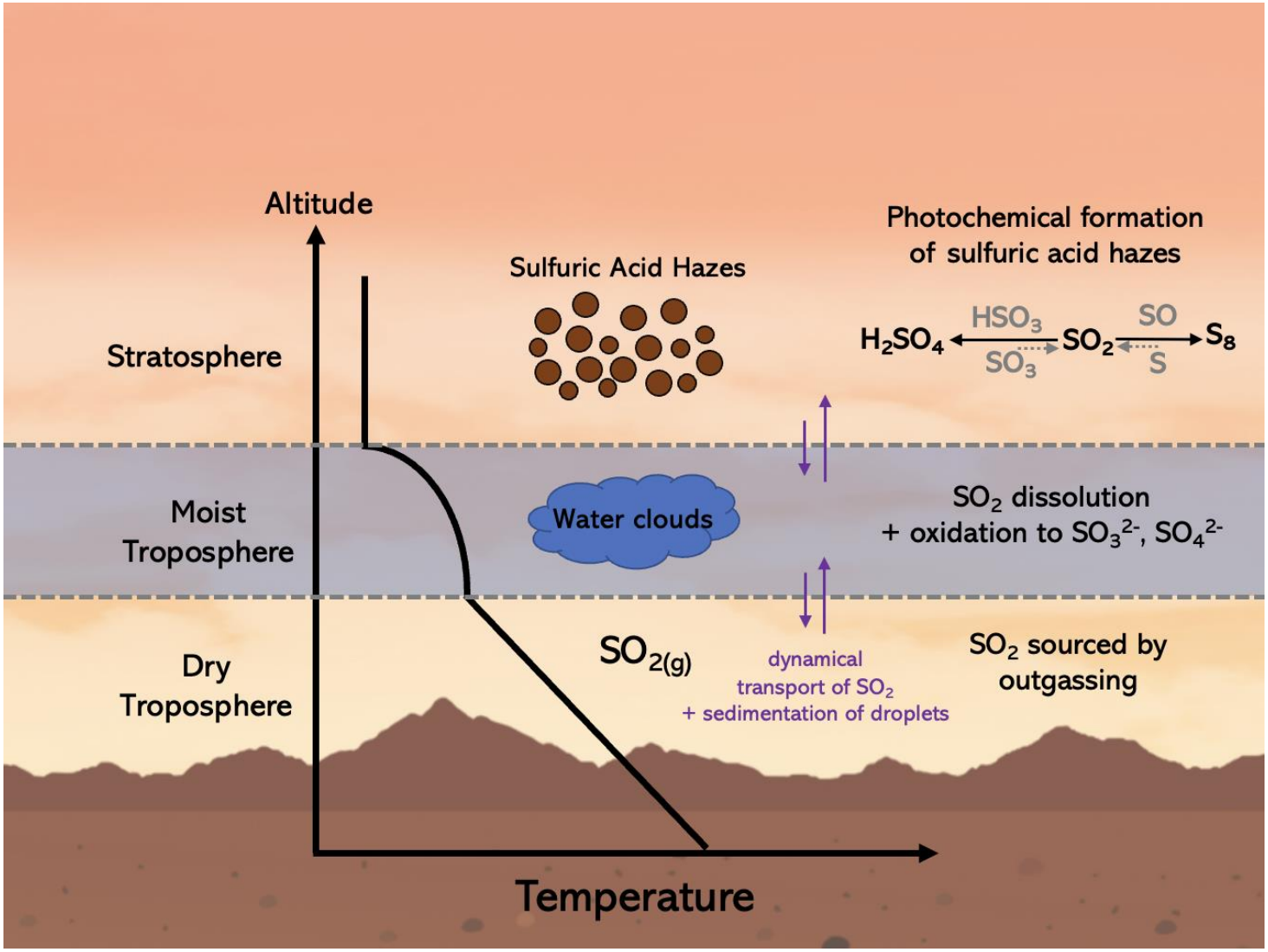


Present-Day Venus

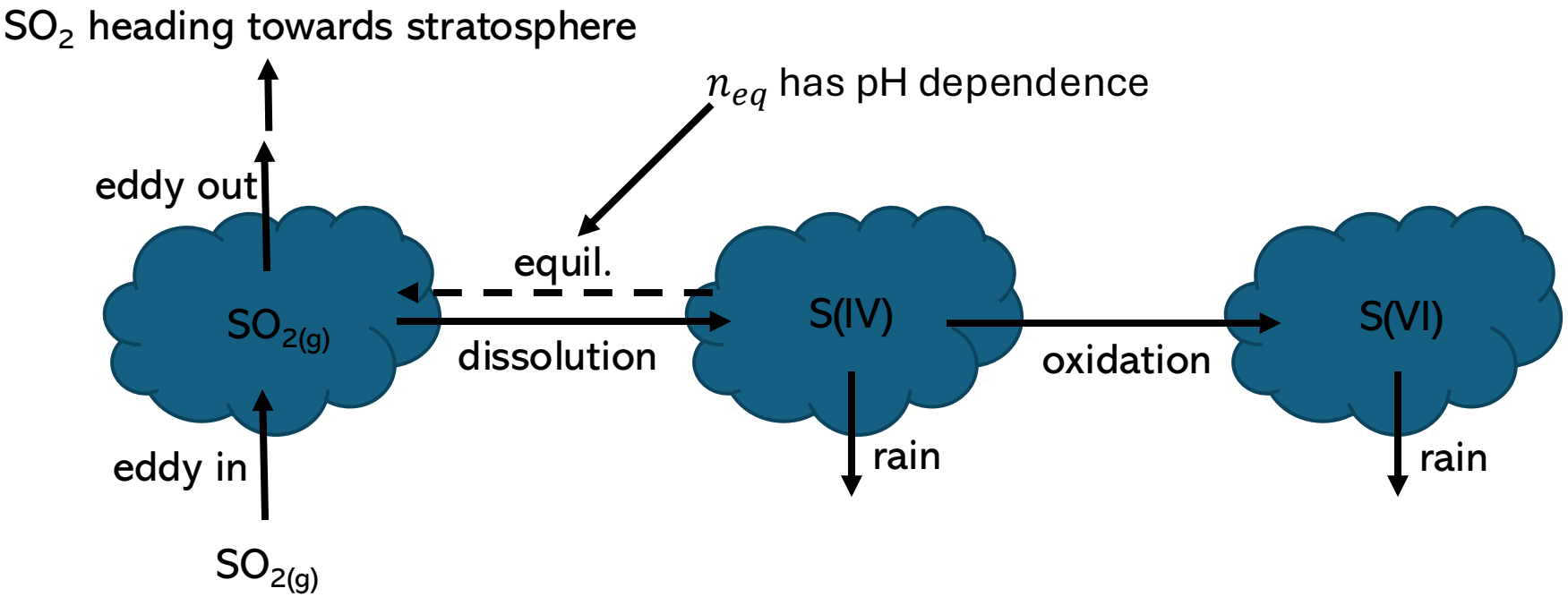
Sulfuric acid hazes contribute to a high albedo at present-day Venus and influence the climate.
(e.g., Tomasko et al., 1980; Bullock et al., 2001)



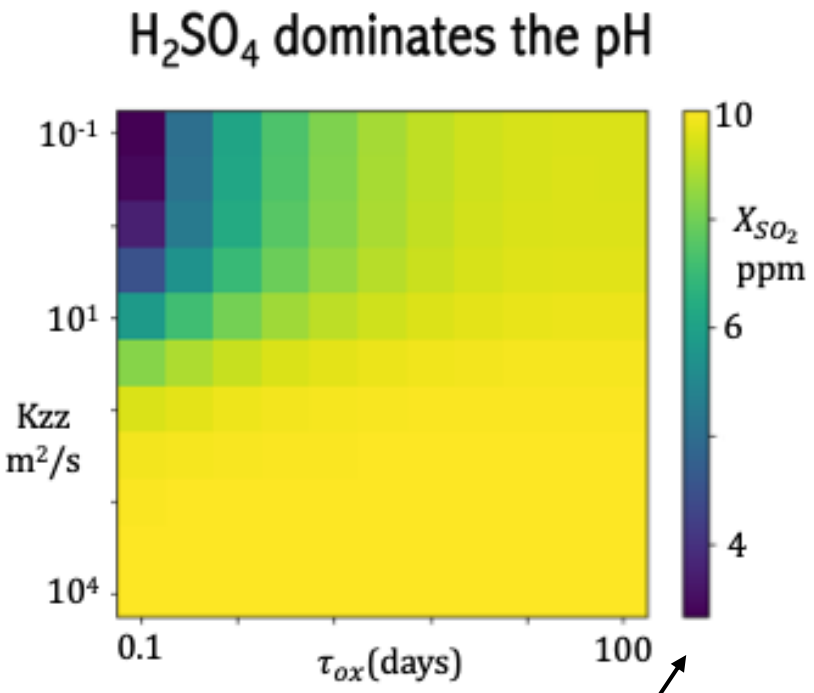
Do Sulfuric Acid Hazes Cool Early Venus-Like Worlds?

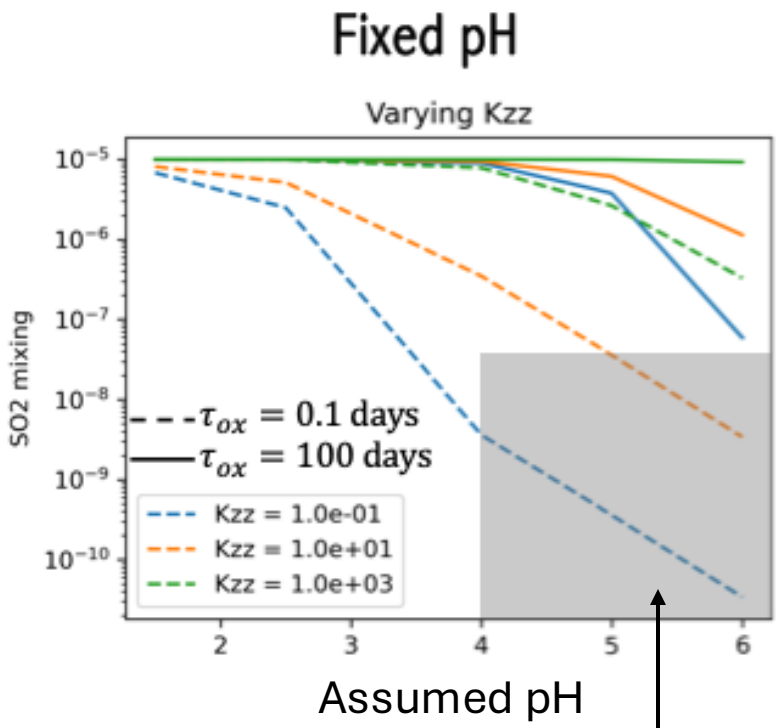


In steamy atmospheres, would SO_2 become cold trapped in water droplets?



SO_2 is generally not cold trapped!



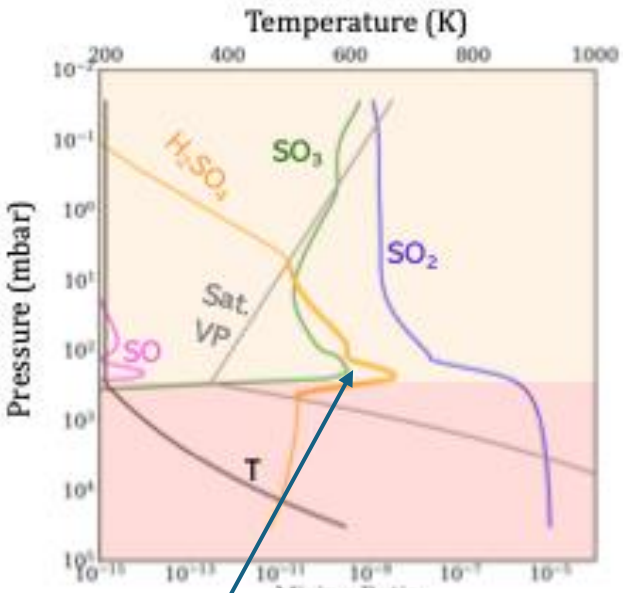


1/3 of initial SO_2 makes it to stratosphere

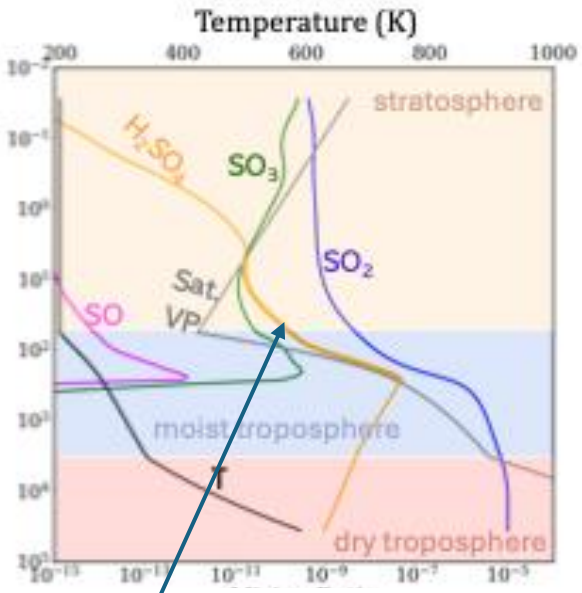
high pH, fast oxidation and slow eddy diffusion timescales needed for large loss of SO_2

H_2SO_4 haze production rate is modified by composition.

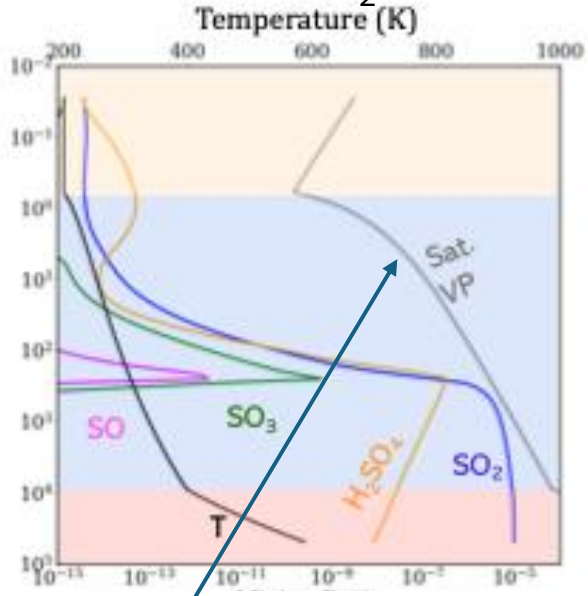
Venus-Like. 1 ppm H_2O



10% H_2O



70% H_2O



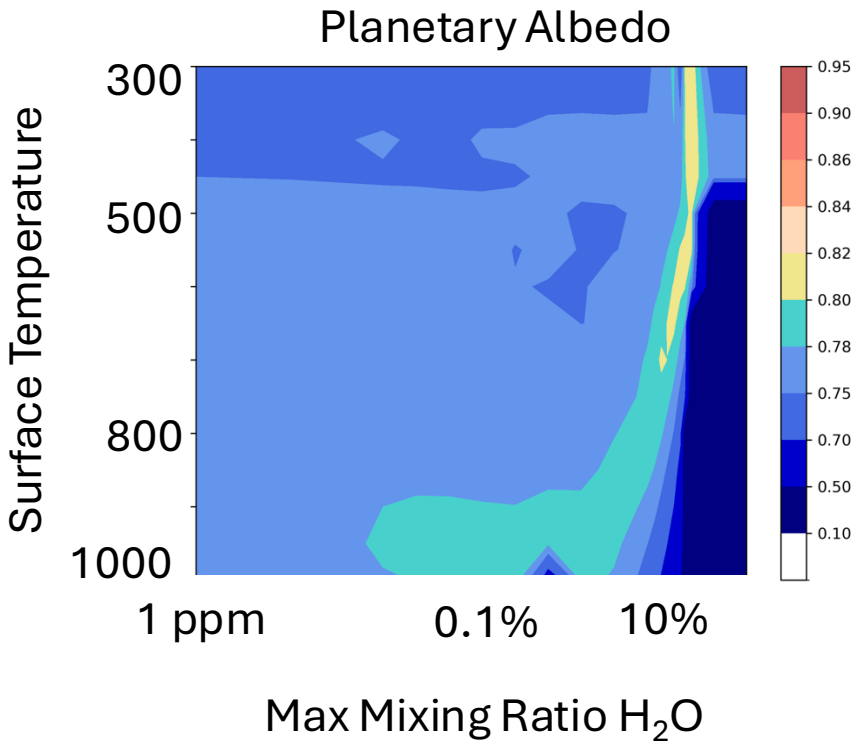
Haze formation

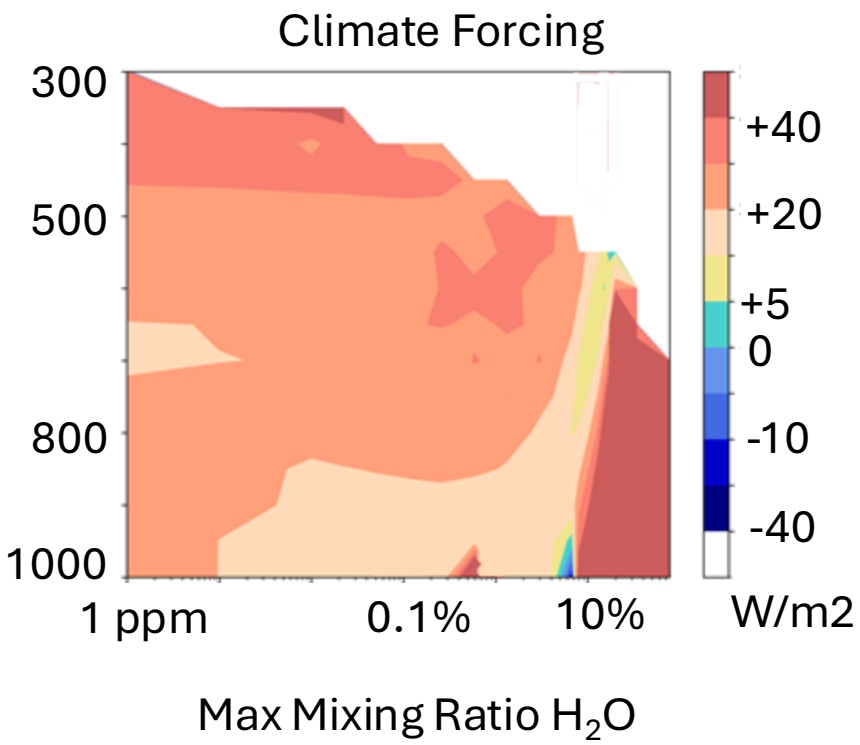
more HOx = faster SO_2 oxidation
= faster haze formation

low μ = puffy atmosphere = warmer high up.
high saturation vapor pressure = no haze.

Sulfuric acid hazes are brightest in ~10% H_2O atmospheres.

The hazes are unlikely to have cooled early Venus for surface liquid water but are potentially important to exoplanet climates.

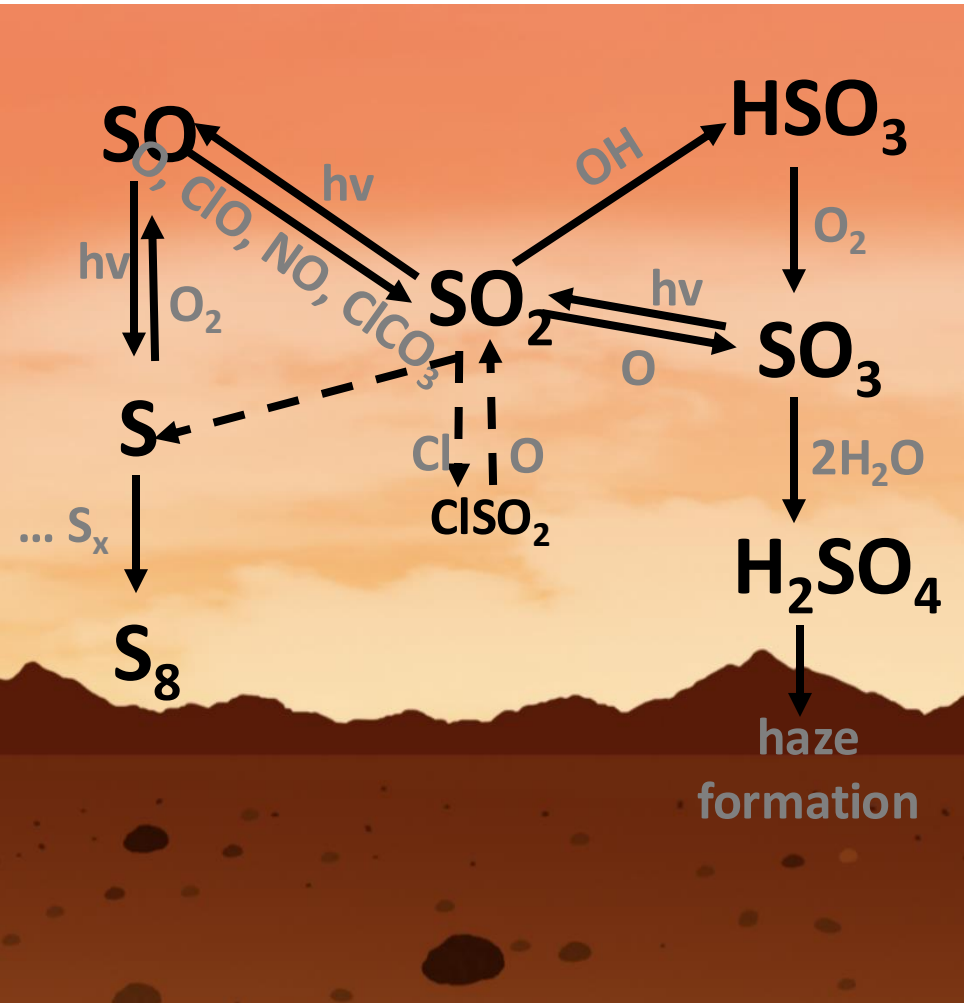




Backup slides

KINETICS in the Stratosphere: Haze Formation

Photochemical formation of H_2SO_4 from SO_2



Formation of H_2SO_4 hazes

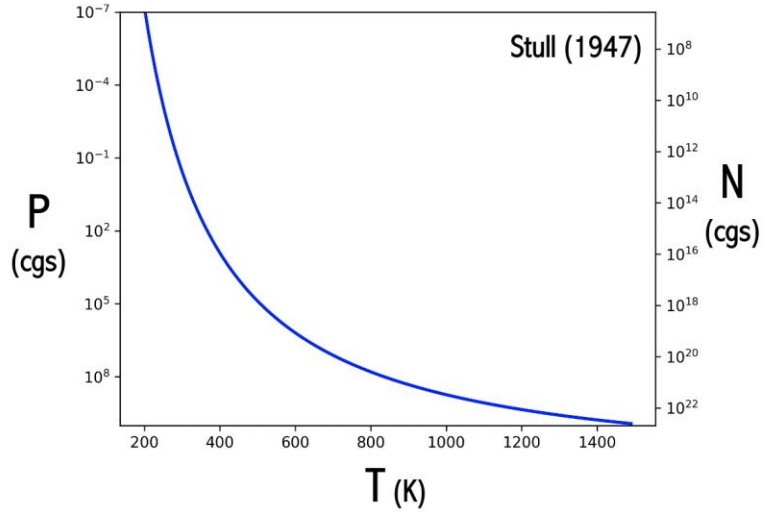
0.3-0.9 um

non-linear dep. on Dp

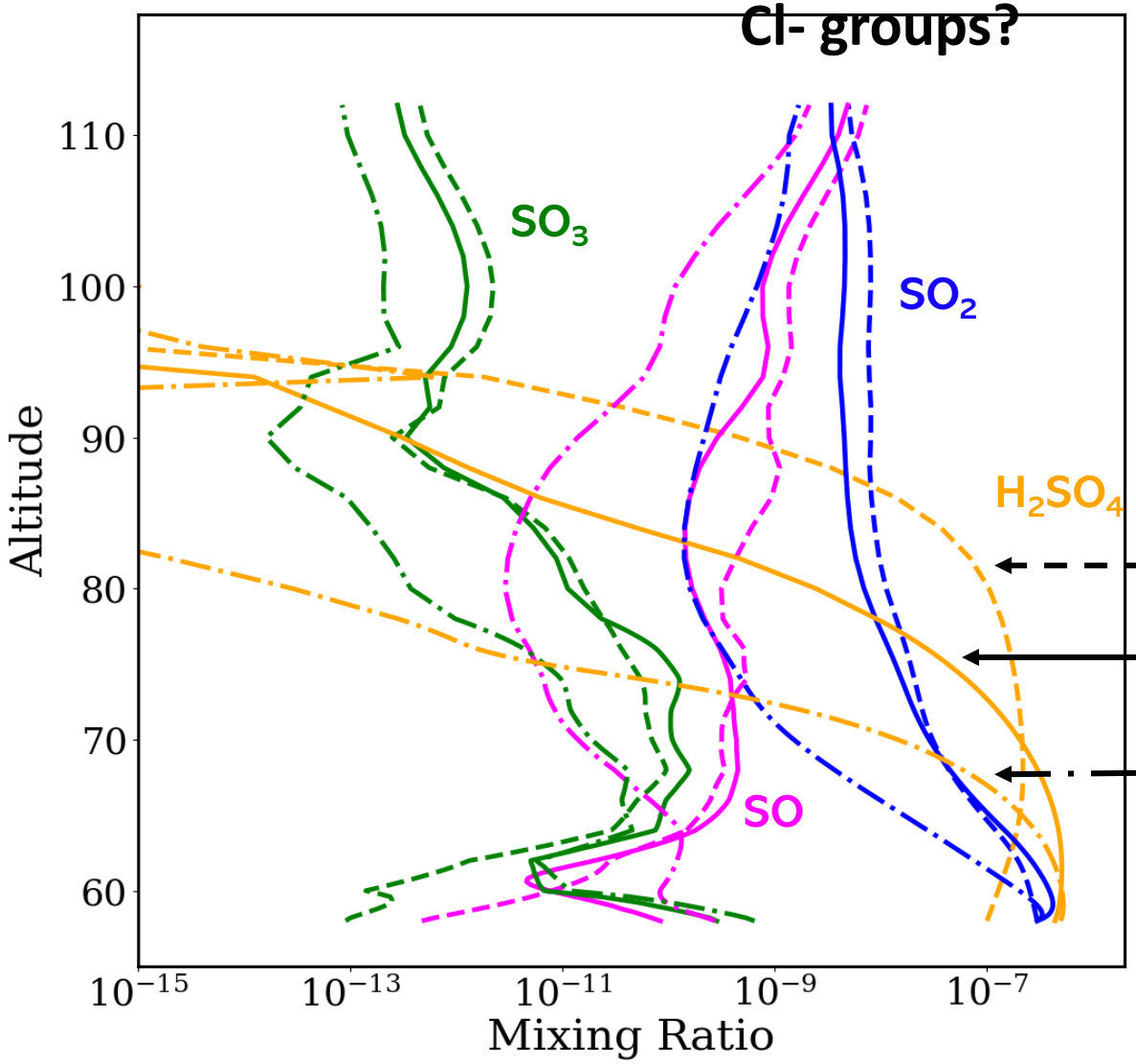
$$\frac{dm}{dt} = \frac{2\pi D_p D_i M_i}{RT} f\,\Delta P$$

Seinfeld & Pandis (2016)

H_2SO_4 Saturation Vapor Pressure



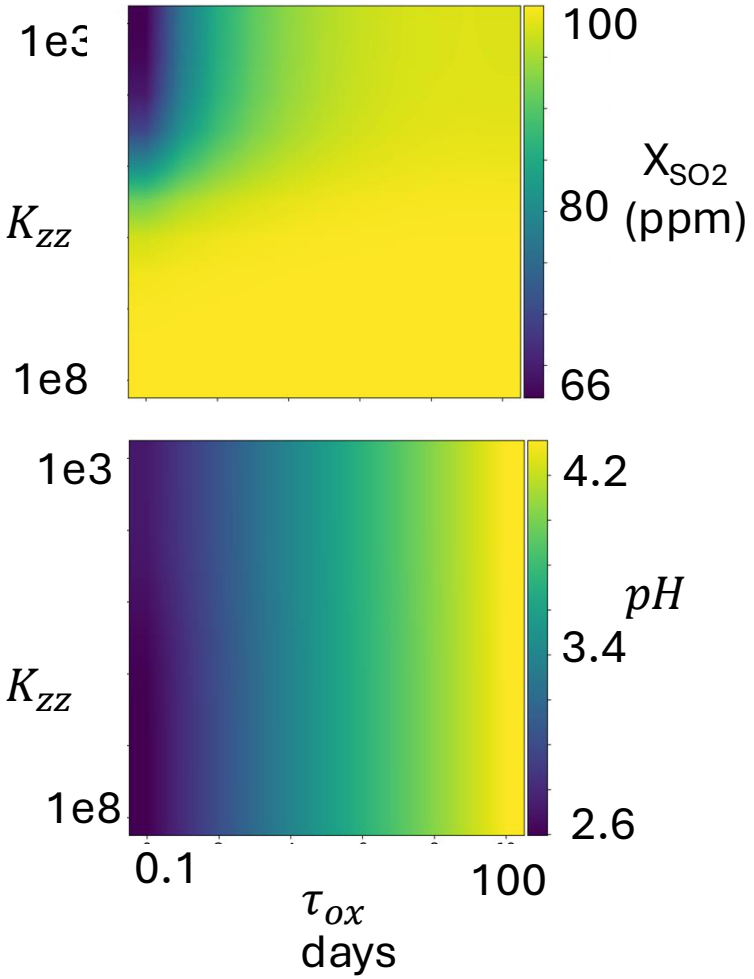
Venus Chemistry: Can we simplify by removing N-, Cl- groups?



It's not perfect, but *underestimates* H_2SO_4 We'll roll with the simple case.

Box Model: How much SO_2 makes it to the stratosphere?

NOT cold-trapped *if* sulfuric acid dominates the pH in the droplet



CAN BE cold-trapped *if* basic species (e.g., NH_3) dominates the pH instead AND either Kzz and/or τ_{ox} are